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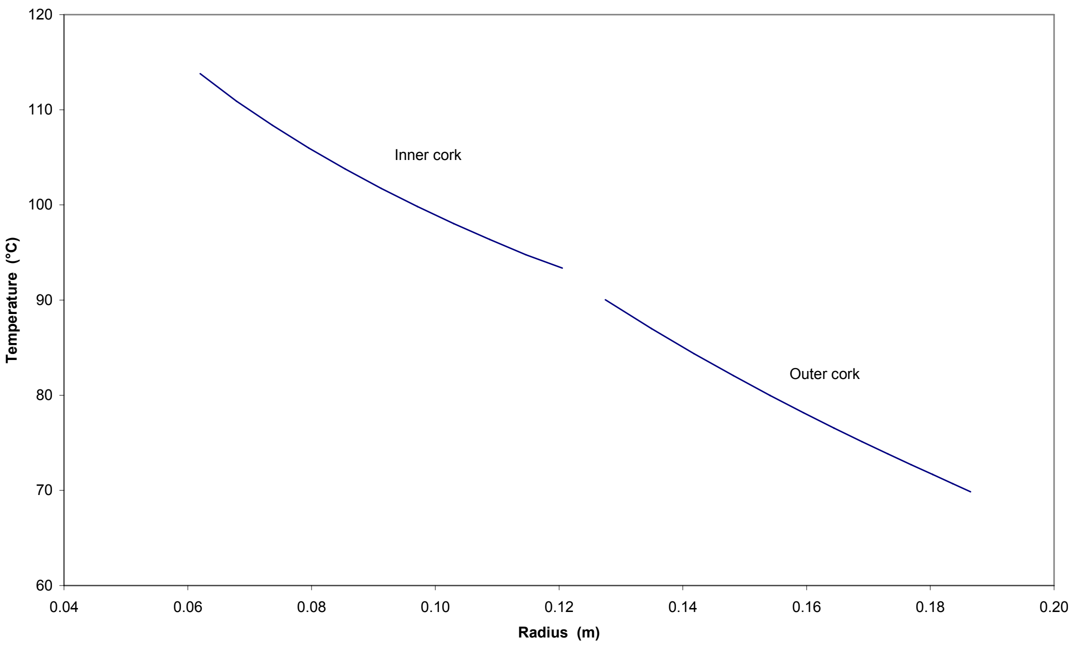
Dear Bob,

Response to comments on thermal performance of SAFKEG LS raised by NRC assessor

As you requested, I have considered the queries raised by the NRC relating to the thermal performance of the SAFKEG LS. My responses to the individual questions raised are given below.

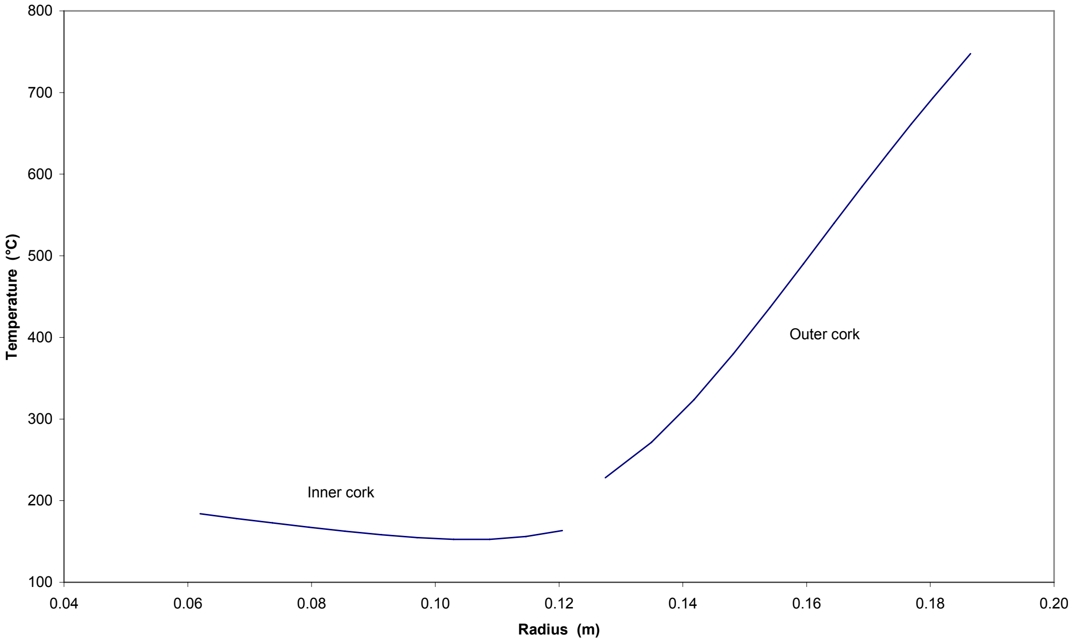
Clarify the cork material's response to the temperatures encountered under the NCT and HAC tests

The graph below shows the maximum temperature experienced by the cork, as a function of radius, under NCT conditions (including insolation). The profile shown corresponds to a horizontal slice at mid-height of the cask.



The maximum temperature experienced by the cork under NCT is 114°C. This is within its long-term operating temperature limits.

The following graph shows the maximum temperature experienced by the cork, as a function of radius, during the 800°C fire test. The profile shown is the same horizontal profile shown for NCT conditions above.



The maximum predicted cork temperature is 747°C. At this temperature the cork chars and degrades but the furnace tests performed on the SAFKEG LS, at somewhat higher temperatures than the 800°C fire test, have demonstrated the ability of the cork to survive for the short time over which high temperature is experienced. The cork on the outside of the cask chars while that away from the cask surface remains essentially intact.

The charring of the cork, and the associated release of water and oils, affects the heat transfer across the cork. In the model this is represented by using an effective thermal conductivity for the HAC calculations. The thermal conductivity, as a function of temperature, is increased so that the predicted maximum temperature experienced by the containment vessel matches that measured in the furnace test. A 50% increase over the normal measured thermal conductivity values was shown to be required. This is described in Section 3.2 of the report.

Sensitivity to air gap width

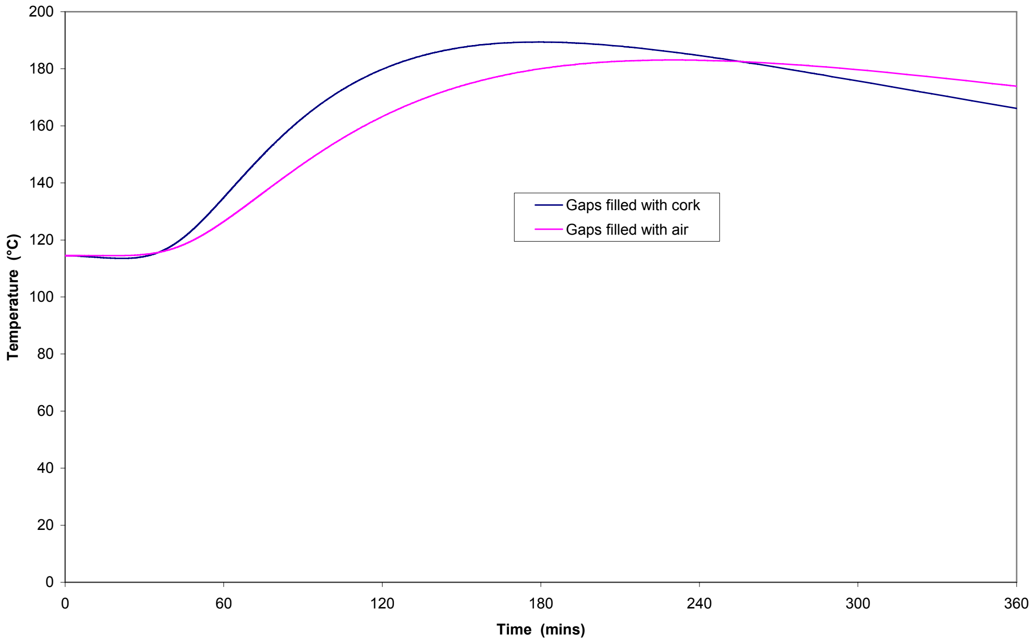
The NCT calculation (cask vertical, 10W heat load) has been re-run with all the cork assumed to have swollen so that all the air gaps around the various pieces of cork are now filled with cork. This was done by modifying the model so that heat transfer across each gap corresponded to conduction through cork rather than conduction and radiation through air.

A transient calculation was performed which included the effect of insolation. Previously it had been concluded that the vertical orientation of the cask was more pessimistic than horizontal orientation. The cask was therefore modelled as being vertical.

The maximum temperature experience at the containment vessel lid seal was predicted to be 114°C. This is 2°C lower than that predicted when the gaps around the cork were filled with air. This reduction in seal temperature results from the thermal conductivity of cork being higher than that of air. The change in temperature is small, however, showing that the air gaps are relatively unimportant in the thermal performance of the SAFKEG LS.

The HAC fire test calculation has also been re-run with the air gaps filled with cork. In this case the thermal conductivity of the cork was assumed to be 50% above its reference value (i.e. the same conductivity as is assumed for the bulk cork – see Figure 4 of the report). Because the temperature of the cask under NCT conditions was predicted to be lower when the gaps are filled with cork than when they are when they are filled with air, the temperature profile corresponding to the gaps being air filled was pessimistically used as the starting point for the fire test calculation.

The predicted temperature, as a function of time, at the containment vessel lid seal is shown in the following graph. The temperature reported previously with the gaps around the cork assumed to be filled with air is also shown for reference.



Modelling the gaps as being filled with cork is seen to enhance the efficiency of heat transfer between the outside of the cask and the containment vessel. The temperature of the containment vessel (as illustrated by the lid seal) therefore increases faster, and the peak temperature is reached earlier, than when the gaps are assumed to be filled with air. The peak temperature reached at the containment vessel lid seal is 189°C (compared to 183°C when the gaps are assumed to be filled with air). This shows that, while the air gaps do provide some insulation of the containment vessel from the heat of the fire, their contribution is modest compared to the insulation provided by the cork.

Air Property Data

The following table gives the thermal conductivity of air which was assumed in the thermal calculations. This thermal conductivity was used to represent heat transfer across the air gaps in the model. The model did not include the thermal capacity of the air. No data was therefore needed for the density or specific heat of air.

Temperature (°C)	Thermal Conductivity (W/m/K)
0	0.0243
100	0.0314
200	0.0386
400	0.0515
800	0.0709

These properties were taken from ‘Atomic Energy Technical Data Sheets – Properties of Substances in SI units’, UDC 53.

Please let me know if you require any further information.

Yours sincerely

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